THE GENUS *ARCHAIAS* (FORAMINIFERA) AND ITS STRATIGRAPHICAL DISTRIBUTION

by A. H. SMOUT AND F. E. EAMES

ABSTRACT. The genus *Archaias* Montfort 1808 was emended by Henson 1950. It includes those species of the Family Peneroplidae which have chambers that contain interseptal pillars but no subepidermal partitions. All species are reviewed and described as far as possible. Additional illustrations are given for Middle East species. The stratigraphical occurrences are also considered.

The genera *Helenis* Montfort 1808, *Ilotes* Montfort 1808, *Orbiculina* Lamarck 1816 (as by previous authors), and *Puteolina* Hofker 1952*a* (*min. pars*) are placed in the synonymy of *Archaias*. *Cyclorbiculina* Silvestri 1937 is not, contrary to usage in leading textbooks.

Species of *Archaias*

(*a*) Valid species:

Nautilus angulatus Fichtel and Moll 1798.
Archaias asmaricus sp. nov.
Nummulites floridanus Conrad 1846.
Archaias hensoni sp. nov.
Archaias kirkukensis Henson 1950.
Archaias operculiniformis Henson 1950.

(*b*) Probable valid species (description inadequate):

Archaias columbiensis Applin and Jordan 1945

(*c*) Species removed from *Archaias*:

Orbiculina adunca var. *flabelliformis* Lister 1903 = *Cyclorbiculina compressa.*
Orbiculina compressa d'Orbigny 1839 = *Cyclorbiculina compressa.*
Orbitolites malabarica Carter 1853 = *Taberina malabarica.*
Orbiculina mamillata Carter 1857 = *Orbitolinopsis sp.* (Provisionally used for *Orbitolina* auctt. because the type species *O. gigantea* d'Orbigny 1857 is a coral.)
Orbiculina rotella d'Orbigny 1846 = *Borelis sp.*
Archaias vandervlerki de Neve 1947 = *Taberina malabarica.*

(*d*) Invalid names (all synonyms of *A. angulatus*):

Nautilus aduncus Fichtel and Moll 1798.
Orbiculina numismalis Lamarck 1822.
Orbiculina nummata Lamarck 1816.
Nautilus orbiculus Fichtel and Moll 1798, *non* Forskål 1775.
Ilotes rotalitatus Montfort 1808.
Helenis spatosus Montfort 1808.
Archaias spirans Montfort 1808.
Orbiculina uncinata Lamarck 1822.

INTRODUCTION

DURING the course of investigations into the Asmari Limestone of Iran and the Main Limestone of Iraq it was found that recognition of *Archaias spp.* gave considerable difficulty. It is now possible to support with additional figures and more complete descriptions the species published by Henson (1950). Two other species mentioned but not formally named by Henson can now be recognized. In the Middle East it is rare to find separate specimens of *Archaias spp.* and even rarer to find ones with visible external structure. The only practical utility of these species is in random thin sections. The difficulties of diagnosis are accentuated by damage to the specimens before and during fossilization, and as found the test is often not a distinct structure but merely an alteration product in hard limestone. The variability of species of the Peneroplidae is notorious and one must always expect a proportion of aberrant specimens. Considerable familiarity with Recent Peneroplidae is highly advisable before attempting determination of such fossil material. Apparently good sections are sometimes difficult to interpret; for

[Palaeontology, Vol. 1, Part 3, pp. 207–25. pls. 39–41, 42 (pars)]

instance, a specimen with a single equatorial row of pillars would give an appearance of having several rows in a section only slightly oblique to the equatorial plane and would show every chamber crowded with pillars in true equatorial section. An axial section usually appears to have more whorls than would be shown by the same test in equatorial sections. This is because the alar prolongations of the chambers are vorticiform and their curvature adds from a quarter to two apparent whorls to the actual spire, particularly when there is a large reniform stage. Cyclical chambers are strictly evolute, but where spiral chambers are strongly curved or there are reniform chambers it may be possible to prepare sections that cut many chambers on both sides of the centre while avoiding alar prolongations, except in the inner whorls. This pseudevolute condition cannot always be distinguished from the true evolute condition. Sections always tend to show a smaller diameter for the nucleoconch than the true one because they are usually slightly out of the exact centre line. The preponderant type of section is related to the shape of the test; some species are seen in random section as more or less axial sections, with rare exceptions, while other species show a high proportion of specimens that look highly oblique or even approximately equatorial. This is caused by the variation in angle from the axial or equatorial section, which is tolerable before the appearance is noticeably changed. In general it is unwise to determine a single specimen; a suite of specimens usually enables one to determine the dominant species but leaves a possibility that related species are present in small numbers.

The distribution of species in the Middle East has definite stratigraphical value. *A. operculiniformis* occurs in the earlier Oligocene (Lattorfian? and Rupelian) and one occurrence in the higher part of the Oligocene (Chattian) has been noticed by us. *A. kirkukensis*, *A. asmaricus*, and *A. hensoni* occur at higher horizons, and overlap with *A. operculiniformis* has not been recognized; their age is given as U. Oligocene and perhaps Lower Miocene by Henson (1950), and Van Bellen (1956) recorded *A. kirkukensis* as ? Middle or Upper Oligocene.

In Gach Saran Wells 6 and 11 of Iran, *A. kirkukensis* is common in the lower part of the Middle Asmari Limestone, while *A. asmaricus* and *A. hensoni* are common in the higher part. Specimens doubtfully assigned to all three species were found throughout. Occurrences in Iraq are mostly of one species in any one section. In the Bajawan Limestone of Kirkuk Well 21, *A. kirkukensis* occurs in abundance, and *A. asmaricus* alone occurs at a slightly higher level (*c.* 20 ft.) in the same formation. Distinction between the Anah and Bajawan formations given here is not always based on conclusive evidence.

The European Stage names used here are intended only as an approximate guide to age. They are used in preference to subdivisions of the Oligocene, which are subject to differences of convention and are even less susceptible to precise definition. We do, however, follow the trend of current opinion in regarding the Aquitanian as Lower Miocene; in Iran the Middle Asmari Limestone (here regarded as Aquitanian in age) immediately underlies beds of Burdigalian age, often in normal succession. Its fauna, which includes *Meandropsina anahensis* Henson 1950 and *Austrotrillina howchini* (Schlumberger) 1893 *sensu stricto*, is definitely more closely related to Burdigalian than to Oligocene faunas. It has in common with the Oligocene of the Middle East the species *Praerhapydionina delicata* Henson 1950, *Peneroplis evolutus* Henson 1950, *P. thomasi* Henson 1950, and *Borelis pygmaea* Hanzawa 1930, but these species are known also from Miocene beds in other areas.

The evolution of species of *Archaias* is not known with certainty. *A. columbiensis* and *A. operculiniformis* may have belonged to the same lineage but were more probably evolved independently from lenticular species of *Peneroplis* such as *P. dusenburyi*. *A. kirkukensis* may have evolved from *P. evolutus*, which has a similar spire; Henson (1950) suggested its derivation from *P. thomasi*, but we think this must have been a *lapsus calami*. *A. asmaricus* so closely resembles *P. thomasi*, which has a longer, overlapping range, that there can be little doubt that it was evolved from that species. *A. hensoni* may be related to *A. kirkukensis*. *A. floridanus* was most probably independently evolved in the West Indies seas and it is possible that *A. angulatus* is descended from *A. floridanus*. There is no reason to assume a close phyletic relationship to the peneroplid species with subepidermal partitions, although there has been extensive taxonomic confusion between species of the two groups.

Acknowledgements. This work is published by permission of the Chairmen, Directors, and Chief Geologists of the Iraq Petroleum Co., Ltd., and the British Petroleum Co., Ltd. We are grateful to Dr. F. R. S. Henson for permission to reproduce certain figures, and to him and Dr. R. C. Van Bellen for discussions during the course of the work; also to the authorities of the British Museum (Natural History) for facilities for the study of specimens, and to those of the Smithsonian Institution, Washington D.C., for the loan of specimens.

DESCRIPTIVE PALAEONTOLOGY

ARCHAIAS Montfort 1808, emended Henson 1950

Helenis Montfort 1808, pp. 194–5 (type species *H. spatosus* Montfort 1808).
Ilotes Montfort 1808, pp. 198–9 (type species *I. rotalitatus* Montfort 1808).
Orbiculina Lamarck 1816, p. 14 (type species *Nautilus aduncus* Fichtel and Moll 1798).
Puteolina Hofker 1952 (*min. pars*), p. 450 (type species *Peneroplis proteus* d'Orbigny 1839, p. 60, pl. 7, figs. 7–11).

Type species Nautilus angulatus Fichtel and Moll 1798 = *Archaias spirans* Montfort 1808.

Diagnosis. The test is composed of porcellaneous shell material, very finely pitted, but perforate only in the very early stages. The chamber walls are distinct and there is no thickening. Interseptal pillars are present in most chambers but there are never subepidermal partitions or secondary septa. The earliest chambers may be empty of pillars and the later ones may be brood chambers with enlarged lumina and reduced pillars. Intercalary whorls have not been recorded in this genus; the spire is always simple and planispiral, typically beginning with a closely-coiled stage, passing through a laxispiral stage and ending with a terminal flare. Some species develop flabelliform or cyclical chambers. The spiral chambers are equitant and mostly fully involute, but in the last whorl the alar prolongations may retreat from the poles. The flare of the spire often results in a central involute boss and a large pseudevolute flange, while cyclical chambers are always evolute. The chambers are usually curved and the alar prolongations vorticiform. This, combined with the radial direction of the margin when the spire becomes aduncate, causes the apparent margin of the adult test to be mostly truncate and occupied by the apertural face, whereas the true margin is rounded. The apertures of the early chambers are basal slits but in most chambers the apertures consist of rows of pores. All known species are dimorphic or trimorphic. The megalosphere is spherical or subspherical and is followed by a distally swollen neck-chamber which in some species is coiled at an angle to the equatorial plane.

Remarks. Following Henson (1950), we define *Archaias* as containing those species of the Peneroplidae that have interseptal pillars in the chambers but no subepidermal partitions or secondary septa.

The original description of the species mentioned subdivided chambers, and it was assumed that these were a normal feature of the genus until Henson demonstrated that the type species had pillars but no subepidermal or other partitions in the chambers. Hofker (1952) confirmed this. It will be found from the synonymy of *A. angulatus* (given below) that this is indeed the true species and, from the redescription, that it is a very distinct species which does not intergrade with any that have subepidermal partitions, in spite of published statements to that effect, e.g. d'Orbigny (1839), Brady (1884), Lister (1903). No known case exists in which such intergradation is suspected and therefore Henson's revision of the genus is maintained, although it differs drastically from all earlier ones.

From the synonymy of *Archaias angulatus* it follows that the genera *Helenis* Montfort 1808, *Ilotes* Montfort 1808, and *Orbiculina* Lamarck 1816 are junior synonyms of *Archaias*.

Cyclorbiculina Silvestri 1937 (type species *Orbiculina compressa* d'Orbigny 1839) has been placed in the synonymy of *Archaias* in many textbooks. This was justified by the usage current before 1950, but becomes impossible after Henson's generic revision. *O. compressa* commonly occurs with *A. angulatus* and has been extensively confused with it, being one of the species with subepidermal partitions that have given rise to misconceptions about the characters of the genus *Archaias*.

Puteolina Hofker 1952 (type species *Peneroplis proteus* d'Orbigny 1839) includes *Archaias angulatus* in the original list of species and Hofker treats *Archaias* as a subgenus of *Puteolina*. *Puteolina* is therefore in part a synonym of *Archaias*. In addition to the nominal defect, we do not consider the relationships of the species involved to be well expressed by Hofker's taxonomic treatment.

Occurrence. Middle Eocene to Recent, tropical to subtropical seas.

Archaias angulatus Fichtel and Moll 1798

Plate 39, figs. 1–5

Nautilus orbiculus Fichtel and Moll 1798, p. 112, pl. 21, figs. *a–d*, *non* Forskål 1775, p. 125.
N. angulatus Fichtel and Moll 1798, p. 113, pl. 22, figs. *a–e*.
N. aduncus Fichtel and Moll 1798, p. 115, pl. 23, figs. *a–e*.
Archaias spirans Montfort 1808, p. 190 (pl.), p. 192.
Helenis spatosus Montfort 1808, p. 194 (pl.), pp. 195–6.
Ilotes rotalitatus Montfort 1808, p. 198 (pl.), 199–200.
Orbiculina adunca (Fichtel and Moll); Lamarck 1816, p. 14.
O. nummata Lamarck 1816, p. 14, pl. 468, figs. 1*a–d*.
O. numismalis Lamarck 1822, p. 609, pl. 21, figs. *a–d*.
O. uncinata Lamarck 1822, p. 610, pl. 23, figs. *a–e*.
O. adunca (Fichtel and Moll); d'Orbigny, *in* de la Sagre 1839, pp. 81–83, pl. 8, figs. 8, 9, 14; *non* 10–13, 15–16.

O. adunca (Fichtel and Moll); Carpenter 1862, pp. 93–99, pl. 8, figs. 7–12, *non* 1–6.
O. adunca (Fichtel and Moll); Brady 1884, pp. 62, 132, 208–9, pl. 14, figs. 1, 2, 5, 6, 10–13, *non* 3, 4, 7–9.
O. adunca (Fichtel and Moll); Flint 1899, p. 304, pl. 50, fig. 1 part.
O. adunca (Fichtel and Moll); Lister 1903, pp. 96–97 part.
O. adunca (Fichtel and Moll); Cushman 1918, pp. 84–85, pl. 33, fig. 3.
Archaias angulatus (Fichtel and Moll); Cushman 1930, p. 46, pl. 16, figs. 1–3, pl. 17, figs. 3–5.
Puteolina (*Archaias*) *angulata* (Fichtel and Moll); Hofker 1952*a*, pp. 461–3, figs. 49–51, *non* 50*b*.

Description. The test is complanate with a median swelling and a large pseudevolute flange. The spire has about 4½ whorls in the microspheric test, the first being closely coiled but the later ones becoming lax, the last forming a flare so that the direction becomes radial and an aduncate termination is formed. All chambers are equitant and the septa are strongly curved. Most chambers are involute to the poles and the alar prolongations follow the spiral set by the septa. The alar prolongations subtend less than a quadrant each. The terminal quadrant of the test has the alar prolongations progressively shortened so that the last ones just overlap on to the disk. An adult test shows slightly depressed septal sutures, and often only the radially directed terminal part of the spire is visible externally. It is very easy to misunderstand the structure and to mistake septa for spire. The only ornament is of very fine, closely crowded pits. The margin of the test is truncate where occupied by the apertural face, rounded where truly marginal. The apertures of the earliest chambers are basal slits, but later chambers have one or two rows of apertural pores along the elongated apertural face. The last four chambers are brood chambers with a greater distance between septa than normal, and with sparse pillars or none at all. Nearly all chambers have interseptal pillars, which have slight ridges running from them towards the edge of the septa. The microspheric form has more than one whorl of juvenile chambers without pillars. The megalospheric test is closely similar to the microspheric one, grows to about two-thirds the size, and has about 3½ whorls; it also has an aduncate termination to the spire. This species is trimorphic and the A1 generation has up to three juvenile chambers without pillars, whereas the A2 generation has all chambers after the neck chamber pillared. The proloculus is always subspherical and the neck chamber is widest proximally; Hofker shows it subtending about 270° but specimens have been seen with it subtending only 90°, while no specimens of the longer type have been seen by us. Possibly this is a character liable to local variation. Brood chambers have not been seen in the megalospheric generation.

Dimensions

Distance between the centres of septa: 0·05 to 0·07 mm.
Average diameter of pits: 0·004 mm.
Pit spacing between centres about 0·01 mm.

Microspheric test:	Whorl no.	1	2	3	4	5
	Septa	?	13	15	23	35

Maximum diameter of test at least 6·0 mm.
About 4 brood chambers, about 0·14 mm. high.
Proloculus diameter 0·01 mm. *fide* Hofker 1952*a*.

Megalospheric test:	Whorl no.	1	2	3	4
	Septa of A2	1	12	18	12

Diameter of A2 megalosphere up to 0·16 mm. *fide* Hofker 1952*a*.
Diameter of whole nucleoconch of A2 form 0·23 to 0·15 mm.
Diameter of whole nucleoconch of A1 form about 0·045 mm.

Remarks. Nautilus orbiculus Fichtel and Moll 1798 is a junior homonym of *Nautilus orbiculus* Forskål 1775, which is a well-known species that occurs off the coasts of Arabia and East Africa, in the Mediterranean Sea, and in other areas; it is now commonly known as *Sorites orbiculus* (Forskål). In the same paper Fichtel and Moll described and figured *Nautilus angulatus* and *N. aduncus*. Montfort (1808), who frequently renamed species for no obvious reason, proposed the names *Archaias spirans*, *Helenis spatosus*, and *Ilotes rotalitatus* respectively for Fichtel and Moll's three species. *Orbiculina* Lamarck 1816 was presumably proposed in ignorance of the availability of Montfort's three genera.

D'Orbigny 1839 stated that *N. orbiculus*, *N. angulatus*, and *N. aduncus* are growth stages of one species, for which he adopted the name *Orbiculina adunca*. It is noteworthy that he was working on material from the West Indies. He described another species from the West Indies as *Orbiculina compressa* but, to judge from his plates, he did not correctly separate the species from '*O. adunca*'. *O. compressa* differs from *A. angulatus* in having subepidermal partitions, and the terminal flare of the spire occurs at a relatively small size, succeeding chambers being either reniform, flabelliform, or cyclical. Brady (1884), Flint (1899), and Lister (1903) all confuse the two species, referring both to *O. adunca*. Cushman (1917) recorded *O. adunca* from the North Pacific but the determination cannot now be confirmed. Cushman (1918) recorded *O. adunca* from the Pleistocene of the Panama Canal Zone, probably correctly.

Cushman 1930, identified *Archaias angulatus*, gave a correct synonymy, and clearly distinguished the species from *O. compressa*. He recorded Recent specimens from waters off Bermuda, Cuba, Porto Rico, Bahamas, Jamaica, and Florida. He also records fossil occurrences in the West Indies, Panama, and Florida, but these are suspect of confusion with *A. floridanus*, particularly those from the Miocene. The specimen figured by Hofker 1952*a*, p. 461, fig. 50*b* is probably *A. floridanus*, not *A. angulatus*.

There has previously been no complete and accurate description of *Archaias angulatus*, although a selective combination of details from Cushman (1930), Henson (1950), and Hofker (1952*a*) would constitute one. Cushman (1930) gave adequate illustrations to make the recognition of *A. angulatus* possible, and the synonymy indicates that, if the species are correctly identified, his choice of name is correct. There are two major difficulties to be overcome. First, Fichtel and Moll (1798) state that *N. orbiculus* was found in the Mediterranean while *N. angulatus* and *N. aduncus* occurred in the Arabian

---

EXPLANATION OF PLATE 39

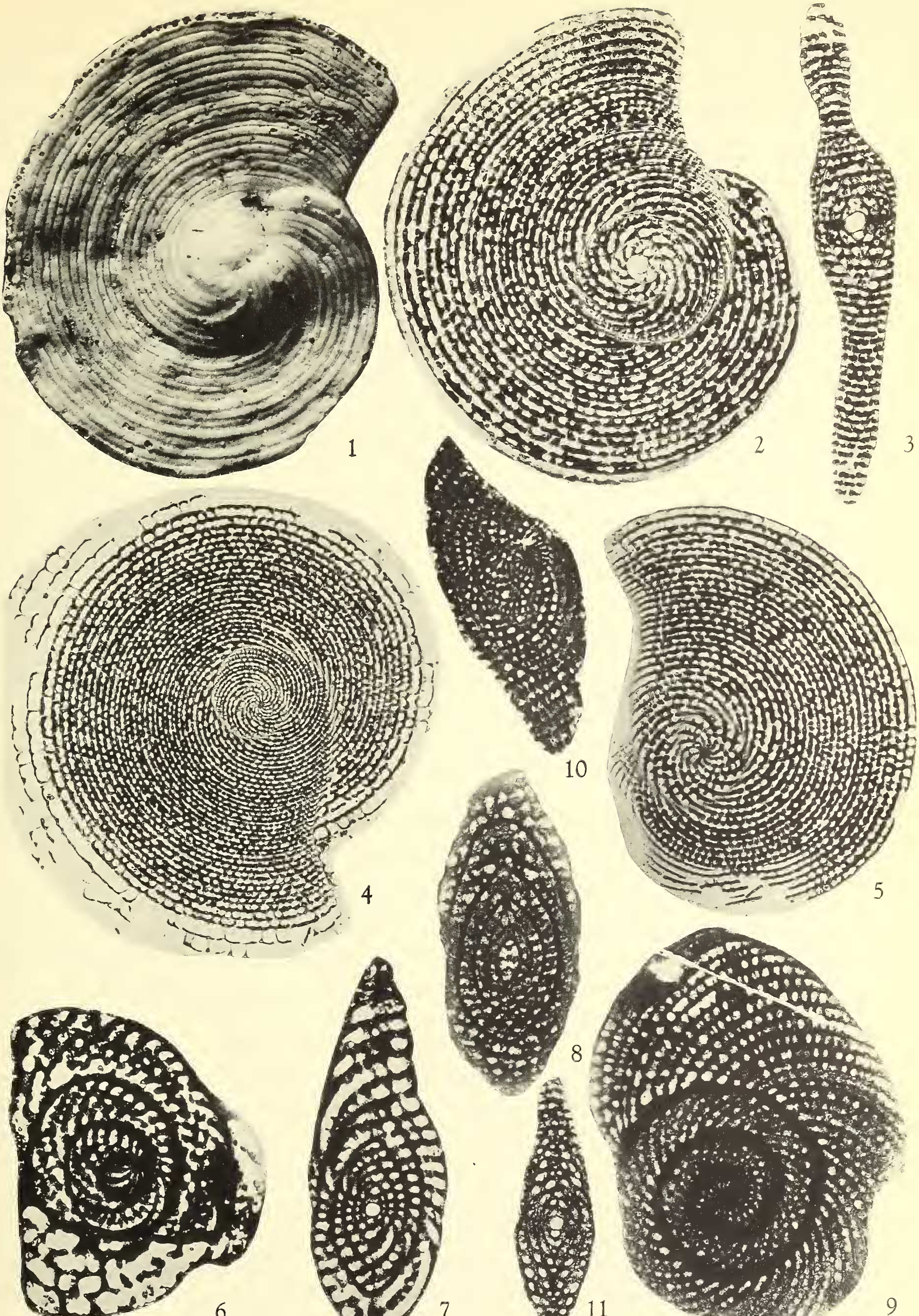
All figures magnified × 20 except Fig. 4 which is × 13.

Figs. 1–5. *Archaias angulatus* (Fichtel and Moll) 1798. Off Barbados; Recent. 1, Exterior of megalospheric test (P. 43706). 2, Equatorial section, megalospheric test (P. 43660). 3, Axial section, megalospheric test (P. 43661). 4, Equatorial section, micropheric test, × 13 (P. 43662). 5, Tangential section parallel to the equatorial plane, megalospheric test (P. 43663).

Figs. 6–9. *Archaias operculiniformis* Henson 1950. 6, 7, Oblique sections, showing the terminal flare and brood-chambers, megalospheric tests; Kirkuk Well 14, Iraq; Shurau Limestone (Oligocene); (6—P. 43707; 7—P. 43664). 8, 9, Axial and equatorial sections, microspheric tests; syntypes (after Henson 1950); Kuh-i-Khamir, Iran; lower part of Khamir Limestone (Oligocene); 8—P. 39712; 9—P. 39711).

Figs. 10, 11. *Archaias sp*. The determination of these apparently good specimens is difficult; (10 after Henson 1950); near Anah, west Iraq; horizon unknown (10—P. 39653; 11—P. 43708).

Numbers in brackets are the registration numbers of the specimens/slides in the British Museum (Natural History).



SMOUT AND EAMES, *Archaias*

Sea. The Caribbean species here called *A. angulatus* is found only in that province and certainly does not occur either in the Mediterranean or in the Arabian Sea. Cushman (1930, p. 47) remarked 'There is much question as to its occurrence in the Mediterranean, and it may be that the authors had West Indian material from some source'. This indeed must have been the case. Both of us, and Dr. Henson, have had many opportunities to find or acquire specimens from Arabia, Africa, India, and the Mediterranean had any existed. It must then be questioned: were Fichtel and Moll's specimens, which are now lost, the same species as that now known as *Archaias angulatus*? Fortunately we have d'Orbigny's identification, although this included specimens of other species which do not seem to have contributed to Fichtel and Moll's plates but possibly did to their descriptions. We have made a careful comparison of these plates with all living species of Peneroplidae and are satisfied that *Nautilus orbiculus*, *N. angulatus*, and *N. aduncus* all represent the same species and that its identification is correct. One must look at these early drawings with the realization that the artist was attempting to illustrate an appearance not a theoretical structure, and that the figures are not to any one scale. The original descriptions and those of many other authors refer to subdivided chambers in this species, but Henson (1950) pointed out that only pillars and not subepidermal partitions were to be found in the chambers; this was confirmed by Hofker (1952*a*). Since the numerous pillars in the chambers can look very like partitions and it requires careful scrutiny to distinguish the two, the errors of description are not surprising. When it is also remembered that *Cyclorbiculina compressa* is usually present in the samples and has subepidermal partitions in the chambers, the error is all too easy to make. All records of cyclical chambers in *A. angulatus* also seem to be based on misidentification of *C. compressa*. Correctly identified flabelliform specimens are rare and most if not all records are based on specimens of *C. compressa* or *Peneroplis proteus*. We have not observed specimens with brood chambers completely devoid of pillars, as stated by Henson (1950). The pillars are usually much reduced, however, and total elimination in some specimens would not be unexpected.

Records of *Archaias* cf. *aduncus* in the Middle East, e.g. Henson (1950), Thomas (1950, 1952), and Turnovsky (1955), refer to specimens of at least four other species but not to *A. angulatus*. One species is *Archaias kirkukensis* two more are named here *A. asmaricus* and *A. hensoni*, and the fourth is either a variety of *A. operculiniformis* or an undescribed species that occurs with it in the higher part of the Oligocene. Henson (1950) distinguished informally between *Archaias* cf. *aduncus* and *Archaias sp. 1*. In most cases his *A.* cf. *aduncus* refers to *A. hensoni* and *A. sp. 1* to *A. asmaricus*, but the diagnostic criteria are not identical and an exact correspondence cannot be maintained. The diagnoses of these species will be found below.

Occurrence. In spite of published statements, the only reliable records of the species are from Recent material from the Caribbean Sea, Gulf of Mexico, and adjacent parts of the western Atlantic Ocean. Records from other areas and fossil records should not be accepted without re-examination of material.

Archaias columbiensis Applin and Jordan 1945

Archaias columbiensis Applin and Jordan 1945, p. 141, pl. 21, fig. 6.

Remarks. The description and figures of this species, as far as they go, agree in all respects with those of *Archaias operculiniformis*, there being at present insufficient data to form a differential diagnosis. It is nevertheless probable that the two are distinct species. *A. columbiensis* seems to be the less inflated. The test is lenticular, bilaterally symmetrical, closely coiled, and has internal structures in the chambers. The chambers are involute and gently vorticiform. The probability is that the species has pillars but no subepidermal partitions, but until this is explicitly demonstrated it is not possible to decide finally if this species should remain in the genus *Archaias*.

Occurrence. Lower Middle Eocene (Lake City Limestone); Columbia county, Florida.

Archaias floridanus (Conrad 1846)

Plate 42, figs. 1, 2

Nummulites floridanus Conrad 1846, p. 399, text-fig.
N. floridanus Conrad; Heilprin 1882, p. 189.
Archaias floridanus (Conrad); Vaughan 1927 (1928), pp. 300–3, pl. 23, figs. 3*a–c*.
A. angulatus (Fichtel and Moll); Cushman 1930 (some fossil records only?), p. 46.
Puteolina (*Archaias*) *angulatus* (Fichtel and Moll); Hofker 1952, p. 463 ('microspheric form'), text-fig. 50*b*.

Description. The test is large and discoidal, fairly thick at the margin, and without a median swelling. The externally visible chambers of the last whorl are all spirally arranged, apparently with vorticiform filaments reaching the poles after more than one revolution. The last dozen chambers in fact progress from reniform to cyclical, but a characteristic radial fold that continues the line of the aduncate termination of the spire makes the whole test appear spiral on cursory examination. Vaughan records that there is 'a short

---

EXPLANATION OF PLATE 40

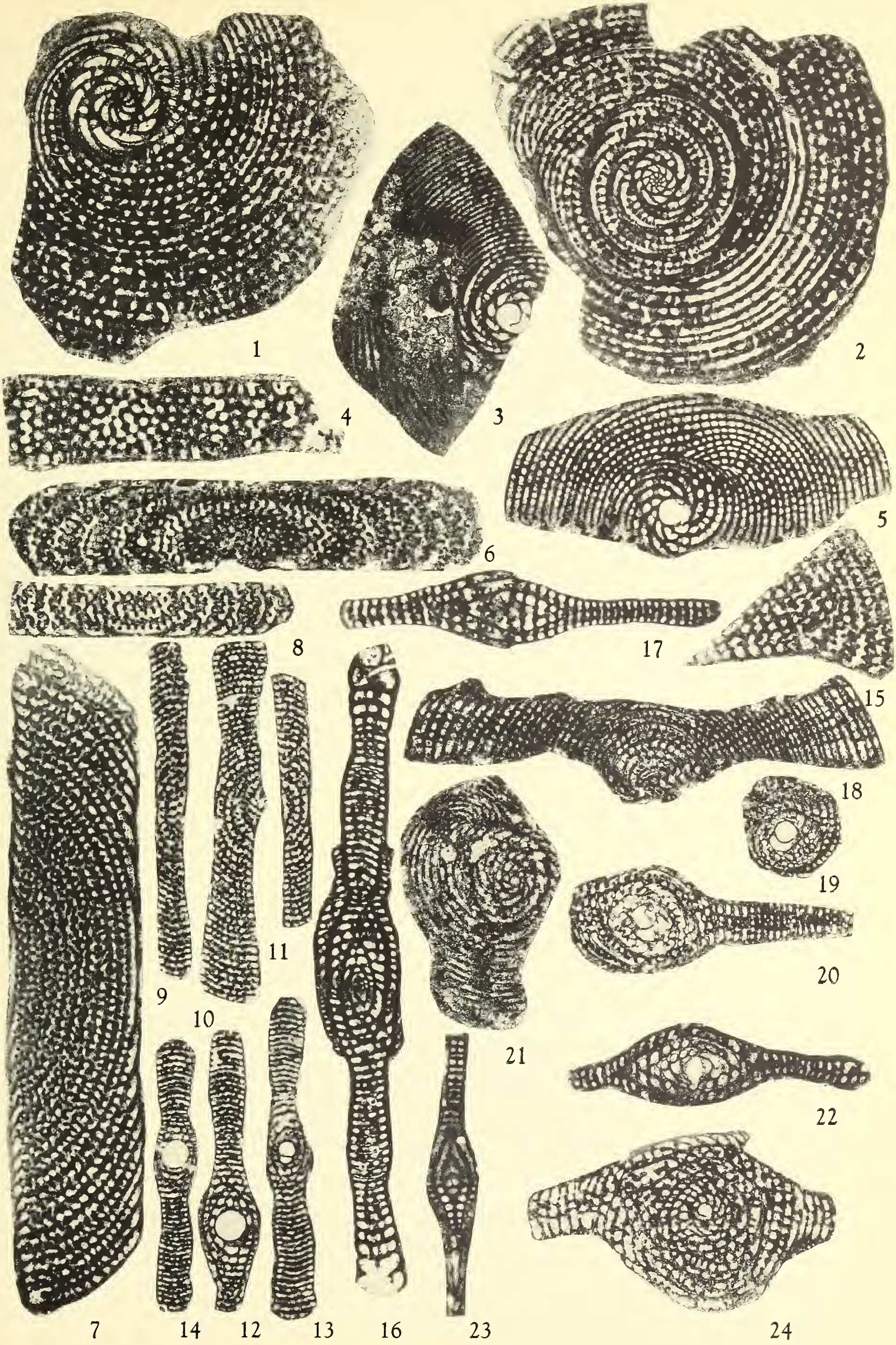
All figures magnified × 20.

Figs. 1–15. *Archaias kirkukensis* Henson 1950, Kirkuk Liwa, Iraq. 1, Nearly equatorial section showing the peripheral empty zone of the chambers where the section has passed tangentially through the earlier chambers, microspheric test. Kirkuk Well 17; Bajawan Limestone (P. 43665). 2, Equatorial section, microspheric test. Kirkuk Well 17; Bajawan Limestone (P. 43665). 3, Nearly equatorial section, megalospheric test. Kirkuk Well 17; Bajawan Limestone (P. 43665). 4, Tangential section through periphery showing the septum with apertures and interseptal pillars. Kirkuk Well 17; Bajawan Limestone (P. 43665). 5, Nearly equatorial section (after Henson). Kirkuk Well 57; Bajawan Limestone (P. 39645). 6, 7, Random sections (7 after Henson). Kirkuk Well 56; Bajawan Limestone (6—P. 43666; 7—P. 39641). 8–11, Random sections. Kirkuk Well 22; Bajawan Limestone (8, 9—P. 43667; 19—P. 43668; 11—P. 43669). 12, 13, Axial sections, megalospheric tests. Kirkuk Well 22; Bajawan Limestone (12—P. 43668; 13—P. 43670). 14, Axial section, megalospheric test. Bai Hassan Well 5; Anah Limestone (P. 43671). 15, Random section. Bai Hassan Well 5; Anah Limestone (P. 43671).

Figs. 16–20. *Archaias hensoni* sp. nov. 16, Axial section, microspheric test (after Henson). Shiranish Islam, north-east Iraq; Aquitanian (P. 39651). 17, Random section (holotype). Anah, west Iraq; ? Anah Limestone (P. 43672). 18–20, Random sections. Ain Zalah Well 1, Mosul Liwa, Iraq; Anah Limestone (18—P. 43673; 19—P. 43674; 20—P. 43675).

Figs. 21–24. *Archaias asmaricus* sp. nov. 21, 22, Random sections. Bai Hassan Well 4, Kirkuk Liwa, Iraq; Anah Limestone (21—P. 43676; 22—P. 43677). 23, Nearly axial section. Kirkuk Well 21, Iraq; Bajawan Limestone (P. 43678). 24, Nearly equatorial section. Near Anah, west Iraq; Anah Limestone (P. 43709).

Numbers in brackets are the registration numbers of the specimens/slides in the British Museum (Natural History).



SMOUT AND EAMES, *Archaias*

nautiloid coil of two or three turns' and 'all the large specimens sectioned were microspheric'. No further information on the structure is available, and the figured specimens are presumably microspheric.

A single British Museum specimen mounted by Lister and labelled '*Orbiculina adunca* microspheric' may be a specimen of this species. It has a different colour and texture from the other specimens of the exhibit and is probably a fossil. It shows the characteristic termination of the spire and the radial wave as in *A. floridanus*. The chambers withdraw from the poles progressively as in *A. angulatus*. The pits are the same as those of *A. angulatus*. The distance between septa is greater, agreeing with those of *A. floridanus*. There are pillars like those of *A. angulatus* and there are no subepidermal partitions. The apertures are numerous and scattered on the apertural face, which occupies all the periphery of the test.

U.S.G.S. specimen f. 3838 from the Lower Miocene of Tampa Island, Cherokee Sink, Wakulla Co., Florida shows a large specimen measuring 10 mm. × 8 mm. and about 0·8 mm. thick at the periphery. It has about six to nine cyclical chambers and several reniform ones, the spire not being visible. The reniform chambers have alar prolongations but the number of degrees that they originally subtended cannot now be seen. The alar prolongations are so related to the earlier whorls that the test is discoidal with little or no polar swelling. The radius of the test at the beginning of the cyclical stage is at least 1·5 mm. The later chambers have nine rows of pillars; they are irregularly arranged, anastomose slightly, and are smaller at the sides of the chamber than in the central region. Subepidermal partitions are absent. Many other specimens of Peneroplidae are present in the same rock but all seem to belong to other species. It is highly probable that both of the above specimens are the same species and correctly identified as *Archaias floridanus*. The British Museum specimen seems to terminate while the test is still spiral, but the Smithsonian one shows the development of a cyclical stage which still has a reniform shape; they both show the kink so typical of *A. floridanus*; in the reniform and cyclical stages the spiral line is continued by a sharp inflexion of the margin.

Dimensions

Maximum diameter 12·25 mm.; most specimens measure 10 mm. or less.
Thirty-three chambers in 4·5 mm. radius.

Remarks. *Archaias floridanus* appears to be a species quite distinct from *A. angulatus*, from which it is easily distinguished by the more discoidal shape, the radial wave and the associated kink in the margin, the development of a terminal cyclical stage, and the chamber spacing. Its attribution to the genus *Archaias* is supported by the new evidence.

Occurrence. Lower Miocene Tampa Formation of Florida. Fossil occurrences of *Archaias spp*. from the Miocene of Panama and the West Indies may be this species but further observation of the material is required before this species can be separated from fossil records of *A. angulatus*. *A. floridanus* has not been found in Recent material.

Archaias operculiniformis Henson 1950

Plate 39, figs. 6–9

Archaias operculiniformis Henson 1950, p. 44, pl. 7, figs. 5, 6.
A. operculiniformis Henson; Thomas 1950, pp. 38, 40.

A. operculiniformis Henson; Kent, Slinger, and Thomas 1951, p. 11.
A. operculiniformis Henson; Thomas 1952, p. 75.
A. operculiniformis Henson; Grimsdale 1952, p. 224.
A. operculiniformis Henson; Turnovsky 1955, pp. 160–1.
A. operculiniformis Henson; Van Bellen 1956, p. 250, pl. 2, fig. *d*.

Description. The test is lenticular with a subacute margin. The spire is comparatively laxly coiled and shows less subdivision into a central, tightly coiled portion and terminal flange than in most species of *Archaias*. The terminal flare shows no recurvature and is therefore not aduncate. The chambers are equitant and probably completely involute throughout. The numerous septa are curved, but less so than is usual in *Archaias*, and the septa therefore never subtend more than a quadrant each. The alar prolongations are gently vorticiform. The epidermis is very thick. The chambers are crowded with interseptal pillars, which are also to be found in the alar prolongations. The species is dimorphic, but not strikingly so. The last few chambers (about four) are brood chambers in the microspheric form and are double the usual height, with much reduced pillars. The megalosphere is small and spherical, with a short neck-chamber which has its distal end swollen. The characters of the earliest chambers are not well known. The apertures are scattered on the apertural face.

EXPLANATION OF PLATE 41

All figures magnified × 30.

Gach Saran Wells 6 and 11, Iran; Middle Asmari Limestone (Aquitanian). Figs. 1–25 from Well 6, numbered mainly in descending stratigraphical sequence; figs. 26–37 from Well 11, numbered mainly in descending stratigraphical sequence.

Figs. 1–5. *Archaias hensoni* sp. nov.; Well 6. 1, depth 3,685 ft., 49 ft. below top of Middle Asmari Limestone (P. 43679). 2, depth 3,701 ft. (P. 43680). 3, depth 3,717 ft. (P. 43681). 4, 5, depth 3,747 ft. (P. 43682).

Figs. 6–8. *Archaias asmaricus* sp. nov.; Well 6. 6, depth 3,846 ft. (P. 43683). 7, holotype, depth 3,844 ft. (P. 43684). 8, depth 3,846 ft. (P. 43685).

Fig. 9. *Archaias sp.*; Well 6, depth 3,847 ft. (P. 43686).

Fig. 10. *Archaias asmaricus* sp. nov.; Well 6, depth 3,847 ft. (P. 43687).

Fig. 11. *Archaias sp.*; Well 6, depth 3,850 ft. (P. 43688).

Figs. 12–19. *Archaias kirkukensis* Henson; Well 6. 12, depth 4,021 ft. (P. 43689). 13, depth 4,120 ft. (P. 43690). 14, 15, depth 4,117 ft. (P. 43691). 16, 17, depth 4,127 ft. (P. 43692). 18, 19, depth 4,130 ft. (P. 43693).

Fig. 20. *Archaias asmaricus* sp. nov.; Well 6, depth 4,130 ft. (P. 43693).

Fig. 21. *Archaias hensoni* sp. nov.; Well 6, depth 4,134 ft. (P. 43694).

Figs. 22–25. *Archaias kirkukensis* Henson; Well 6. 22–24, depth 4,134 ft. (P. 43694). 25, depth 4,143 ft., 117 ft. above base of Middle Asmari Limestone (P. 43695).

Fig. 26. *Archaias hensoni* sp. nov.; Well 11, depth 5,500 ft., 115 ft. below top of Middle Asmari Limestone (P. 43696).

Fig. 27. *Archaias asmaricus* sp. nov.; Well 11, depth 5,586 ft. (P. 43697).

Figs. 28–29. *Archaias hensoni* sp. nov.; Well 11, depth 5,632 ft. (P. 43698).

Figs. 30–37. *Archaias kirkukensis* Henson; Well 11. 30, depth 5,682 ft. (P. 43699). 31, depth 5,811 ft. (P. 43700). 32, depth 5,802 ft. (P. 43701). 33, depth 5,895 ft. (P. 43702). 34, depth 5,992 ft. (P. 43703). 35–36, depth 6,045 ft. (P. 43704). 37, depth 6,107 ft., 43 ft. above base of Middle Asmari Limestone (P. 43705).

Numbers in brackets are the registration numbers of specimens/slides in the British Museum (Natural History).

SMOUT AND EAMES, *Archaias*

Dimensions

Microspheric test:	Maximum diameter 3·6 mm.						
	Whorl no.	1	2	3	4	5	6
	Septa	?	?	27	26	34	34+
	Septa spaced about 0·06 to 0·09 mm.						
	About four brood chambers.						
Megalospheric test:	Maximum diameter 2·6 mm.						
	Thickness at poles 1·0 to 1·5 mm.						
	Diameter of proloculus 0·17 mm.						
	Diameter of nucleoconch 0·28 mm.						
	Whorl no.	1	2	3	4		
	Septa	?	?	?	40?		

Remarks. The lenticular shape, the lack of a cyclical or flabelliform stage, and the rudimentary development of the terminal flange distinguish this from all known species of *Archaias* except *A. columbiensis*. The terminal flare is so short and the chambers so little recurved that no axial section will show it on both sides of the test. The details of the chambers and pillars are such that fragments cannot always be distinguished from those of *A. hensoni*, &c. The specimens illustrated on Pl. 39, figs. 10, 11 show the difficulty. Fig. 10 was called *Archaias sp. 1* by Henson (1950). It is not certain that it is *A. operculiniformis*, and it might be *A. hensoni* or an undescribed species. There is no satisfactory known difference between *A. operculiniformis* and *A. columbiensis*, but in view of the different geological age and the wide geographical separation it is not likely that the species are synonymous.

Occurrence. Oligocene Khamir limestone and Lower Asmari limestone of Iran, Shurau Limestone of Iraq; Lattorfian?, Rupelian, Chattian.

This species was originally described from the Oligocene part of the Khamir limestone of south-west Iran. Thomas (1950, 1952) recorded it in the Asmari limestone. In Iraq the species occurs commonly in the shoreward part of the Shurau limestone with a fauna that includes *Austrotrillina paucialveolata* Grimsdale 1952, *Peneroplis glynnjonesi* Henson 1950, *Quinqueloculina spp. P.* cf. *evolutus* Henson 1950, and *Heterillina hensoni*, cf. Van Bellen 1956. In Iran, in Gach Saran Wells 6 and 11, we find *A. operculiniformis* in a miliolite intercalated between forereef type limestones of the Lower Asmari Limestone with *Nummulites intermedius* (d'Archiac) 1846 above and below but with *Lepidocyclina* above only. The accompanying fauna of the miliolite includes *Austrotrillina sp.* (not easily distinguished from *A. paucialveolata* or *A. howchini* and presumably intermediate in character), *Peneroplis thomasi* Henson 1950, *P. evolutus* Henson, *Praerhapydionina delicata* Henson, and *Bullalveolina bulloides* (d'Orbigny) 1826. A single occurrence at the top of the Lower Asmari Limestone in Gach Saran Well 6 suggests survival of *A. operculiniformis* into the Chattian, i.e. above the range of *Nummulites intermedius*. *Archaias* cf. *aduncus* with *A. operculiniformis* is recorded by Thomas (1950) from Tang-i-Gurgurda, near Gach Saran. These specimens may be from the same bed as that at the top of the Lower Asmari Limestone seen in Gach Saran Well 6, where a proportion of the specimens cannot be identified specially and may not be *A. operculiniformis*. The Shurau limestone resembles the band that carries the main occurrence of *A. operculiniformis* in Gach Saran; the Sheikh Alas limestone below contains *Nummulites intermedius*, and the Baba limestone above, *N. intermedius* and *Lepidocyclina spp*.

Archaias kirkukensis Henson 1950

Plate 40, figs. 1–15; Plate 41, figs. 12–19, 22–25, 30–37

Archaias kirkukensis Henson 1950, p. 43, pl. 7, figs. 3, 4, 9, pl. 8, figs. 1–5.
A. kirkukensis Henson; Turnovsky 1955, p. 156.
A. kirkukensis Henson; Van Bellen 1956, p. 250, fig. 1*a*.

Description. The test is discoidal to biconcave and has a central boss only in the very early stages of growth. The microspheric form has a spire of about 5½ whorls and the megalospheric of about one whorl, in both cases ending in a terminal flare with only a trace of aduncate recurvature. This is followed by a reniform stage of about seven chambers, succeeded by cyclical chambers forming about half the diameter, or more, of the test. The earlier spiral chambers are involute; it is not known how the transition to the evolute cyclical stage is effected but probably it is abrupt. The reniform stage does not make a strong nick in the margin and it is soon abolished by later cyclical chambers. The spiral chambers are strongly curved; the apertural face occupies most of the margin before the test has attained a quarter of its final diameter. The chambers are mostly filled with crowded pillars, which may form up to six rows in the later chambers, but the pillars leave narrow lateral empty zones and are sparse in the alar prolongations of the spiral chambers. In the first three whorls of the microspheric test and the first one or two chambers of the megalospheric test there may be no pillars and the immediately succeeding chambers may have only a single row of pillars per chamber. The apertural face is densely crowded with apertural pores, about seven across in the largest chambers, but not arranged in rows. Brood chambers have never been found. The epidermis is thin. The megalosphere is spherical; the neck chamber subtends about 100° and is usually in the equatorial plane. It is uncertain if this species is trimorphic; apparently small megalospheres may be inaccurately equatorial sections.

Dimensions

Microspheric test: Maximum diameter of test 9 mm.
Maximum thickness of test (margin) 1·1 mm., often less.
Reniform stage begins at about 1·7 mm. diameter.

Whorl no.	1	2	3	4	5	6	Reniform	Cyclical
Septa	9	9	10	11	12	13	7	20

The septa are usually about 0·07 mm. apart but may be more than 0·1 mm. apart (14 to 20 per mm.).

Megalospheric test: Maximum diameter of test 3 mm.
Maximum thickness of test 0·3 mm. (poles and margin).
Minimum thickness of test 0·2 mm. (at beginning of cyclical stage).
Reniform stage begins at 0·6 to 1·0 mm. diameter, not 0·33 mm. as stated by Henson.

Whorl no.	1	2	Reniform	Cyclical
Septa	9	9	9	14

Septa about 0·07 mm. apart (14 per mm.).
Diameter of megalosphere 0·18 to 0·24 mm.
Maximum diameter of nucleoconch 0·26 mm. to 0·35 mm.

Remarks. This species is unusual in having a very short spiral stage, which appears longer than it really is in axial section because the alar prolongations of the chambers are strongly vorticiform. It has a large cyclical disk, only very few specimens showing a polar swelling. The cyclical development and discoidal shape distinguish it from *A. operculiniformis*. The species *A. angulatus*, *A. asmaricus*, and *A. hensoni* have substantial polar swellings that only very rarely are reduced to the size of the most swollen specimens of *A. kirkukensis*. The spiral stage of all these species is larger, with more whorls than in *A. kirkukensis*. *A. asmaricus* is further distinguished by the single equatorial row of pillars and the thicker epidermis.

All the diagnostic characters are difficult to observe in random thin sections. The most useful practical diagnosis is the rarity of any visible central boss in random section, and the complete absence of any substantial lenticular development.

Occurrence. Middle Asmari Limestone (Aquitanian) of Iran. Bajawan and ? Anah Limestone of Iraq.

Archaias hensoni sp. nov.

Plate 40, figs. 16–20; Plate 41, figs. 1–5, 21, 26, 28, 29

Archaias cf. *aduncus* Henson 1950 (*pars*), p. 44, pl. 8, figs. 6, 7.
Archaias cf. *aduncus* Thomas 1952 (*pars*), p. 75.

Description. The test is discoidal, with a narrow flange and a swollen central boss that occupies about half of the diameter. It is probable that the test terminates at the end of the spiral stage. A few reniform or cyclical chambers might be produced, but good equatorial sections have not been seen, nor have whole specimens which are not totally embedded in rock been found. There is little difference between the megalospheric form of this species and that of *A. asmaricus* except that the flange is slightly thicker and there is more than one row of pillars in the later chambers. This makes the resemblance to *Peneroplis thomasi* much less than is the case with *A. asmaricus*, but the thick epidermis seems still to be present. The spire is probably different, but direct comparison is impossible with existing specimens. The megalospheric form has at least five whorls and two brood-chambers.

A new specific name is considered justified by the present additional information, which enables practical distinction of the species from *A. kirkukensis* and *A. asmaricus*. *A. floridanus* is more robust, has more numerous pillars, and has even more vorticiform alar prolongations of the chambers. *Archaias angulatus* also has a more robust flange and much more numerous pillars; its epidermis is thin. The termination of the spire of *A. hensoni* is unknown, but it is most unlikely that it has the exaggerated aduncate flare of *A. angulatus*. In random sections there is a preponderance of specimens showing a thin disk and substantial median swelling, contrasting with the thick disk without median swelling of *A. kirkukensis*, Distinction from *A. asmaricus* depends on determining the number of rows of pillars in the later chambers. The latter species shows a proportion of random sections cut obliquely and making one row of pillars look like two or three, but always includes sections in which the single row is clearly present.

Dimensions

Microspheric test: Maximum diameter 5·1 mm.
Thickness at poles 0·7 mm.
Thickness of flange 0·28 mm.